

Storage in Action and Lessons Learned

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Examples

- Commercial Operation
 - Golden Valley EA (Fairbanks, A/S, balancing, NiCd)
 - Kauai Electric (Kauai, A/S, ramp control, lead-acid)
 - Hawaiian Electric (several islands, several services)
 - Beacon Power (New York, frequency regulation, flywheel)
 - *AES Laurel Mountain (West Virginia, A/S, Li-Ion)*
- Pilot
 - XCEL Energy (Minnesota, NaS)
- Microgrid
 - Santa Rita Jail (California, microgrid)

Golden Valley Electric Association



- Location: near Fairbanks, Alaska
- Capacity: 23MW/6.75 MWh or 46 MW/3.83.MWh
- Technology: NiCd cells + off-the-shelf balance of plant
- Application(s): Frequency regulation, voltage support, spinning reserve, stabilization, black start
- Alternatives: Static var compensation + oil-fired generation
- Cost: \$35 million (2003), funded by customers
- Operating reliability: High
- Efficiency: 90% slow charge, 80% fast charge
- Expected service life: 20-30 years for plant, 12 years for NiCd cells
- Web link: <http://www.gvea.com/energy/bess>

Kauai Electric



- Location: Kauai, Hawaii
- Capacity: 1 MW/1.5 MWh and 3 MW/2MWh installations
- Technology: Lead-acid (Xtreme Power)
- Application(s): Frequency regulation, voltage control, ramp control
- Alternatives: Mix of oil-fired generation technologies
- Cost: \$~4 million, funded by consumers
- Operating reliability: High
- Expected service life: depends on duty cycle
- Solar ~10% of daily peak, frequent ramps due to cloud cover, ramp control tuned to balance storage duty cycle cost with fossil-fired duty cycle costs

Hawaiian Electric



- Capacity: 1125 kW/500 kWh (Lanai), 10 MW/20MWh (Maui), 15 MW/10 MWh (Oahu)
- Technology: various
- Application(s): Frequency regulation, ramp control, spinning reserve, under- and over-frequency mitigation
- Alternatives: Mix of oil-fired generation technologies
- Cost: services delivered under PPAs
- Issues: AGC integration on Maui, unspecified contractual failures, fire



Context is Important

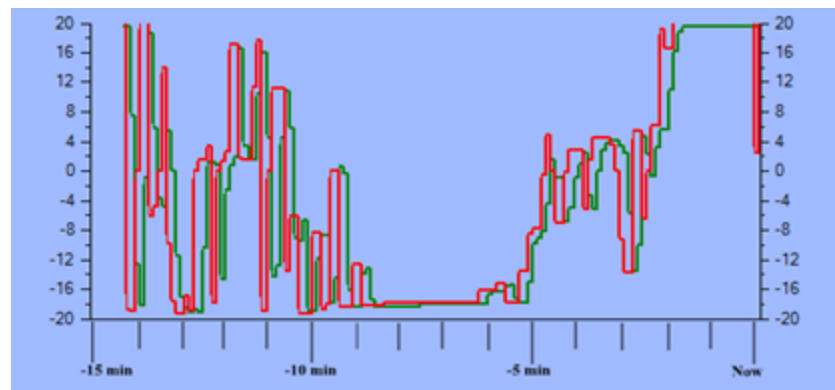


- What makes sense in Hawaii and Alaska won't necessarily make sense in California
 - Hawaii relies on fuel oil at \$180/MWh for running costs alone
 - Alaska relies on diesel fuel at \$300/MWh or more for running costs alone
 - Running cost for oldest gas-fired CTs in California is less than \$80/MWh
 - Grids in Hawaii and Alaska are small and isolated



Beacon Power Stephentown

- Location: Stephentown, New York
- Market Area: New York ISO
- Capacity: 20MW/5 MWh
- Technology: Flywheel
- Application(s): Frequency regulation
- Cost: \$69 million ^{1, 2}
- Operating reliability: 97.5% during startup, 99.3% in Q3 2012*. Two flywheel failures (summer, 2011) in 3 million flywheel operating hours*.
- Operating performance: ~4,000 equivalent full charge/discharge cycles/year*. 95% NYISO accuracy score while following regulation signal. Successful pilots with NYISO, CAISO, ISO-NE.
- Efficiency: 85%
- Design life: 20 years, ~100,000 full charge/discharge cycles
- Web link: http://www.beaconpower.com/files/EESAT_2011_Final.pdf



¹ Clean Energy Action Project

² Estimated cost for a similar plant under construction in Pennsylvania is \$53 million

* Data provided by Beacon

XCEL Energy Wind-to-Battery Pilot

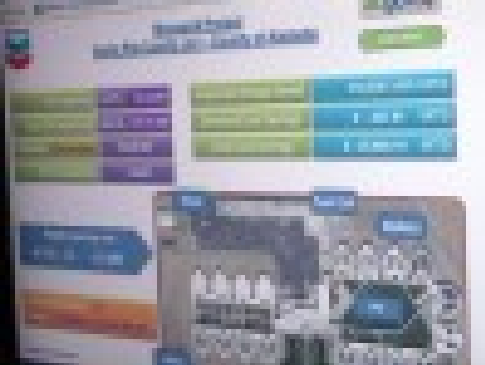


- Location: Luverne, Minnesota
- Capacity: 1 MW/7MWh
- Technology: NaS (NKG)
- Application(s): Frequency regulation, wind leveling, ramp control, time-shifting, economic dispatch
- Cost: ~\$4.6 million, funded by consumers
- Operating reliability: High
- Efficiency: 68-77% overall, 85-92% battery only
- Expected service life: 20-30 years for plant, 12 years for NiCd cells
- Web link:
<http://www.xcelenergy.com/staticfiles/xcel/Corporate/Renewable%20Energy%20Grants/Milestone%206%20Final%20Report%20PUBLIC.pdf>

XCEL Energy Wind-to-Battery Pilot

Selected Findings/Lessons

- Battery charging capacity equal to 20-40% of wind capacity seems best for time-shifting assuming 7kWh storage for each kW of charge/discharge capacity
- Good (but imperfect) control system response to AGC and other signals, likely due to lack of operating experience, control system bugs, and the need for tuning.
- Economic dispatch value is small – “ideal” net revenue of \$445 in test period was substantially diminished by RT schedule deviations and auxiliary power costs
- Charge rate limits as SOC exceeds 93% effectively limits operation in certain applications.
- U of Mn report suggests average annual revenues under “ideal conditions” of \$80/kW/year for economic dispatch and \$120/kW/year for frequency regulation.



Santa Rita Jail Microgrid

- Location: Alameda County, CA
- Capacity: 2MW/4 MWh
- Technology: Li-Ion (lithium-ferrous-phosphate)
- Application(s): Peak demand management, backup power, islanding capability. High supply reliability requirement.
- Cost: ~\$4 million (battery), funded by CEC and DOE grants
- Operating reliability: High, but system integration challenges remain.
- Expected service life: 5000 deep cycles
- Other issues: C&I tariff gets in the way of managing operation to minimize costs, CPUC DG rules unclear on status of storage

Takeaways (1)

- Each storage application and each circumstance is different. Pick the right technology, sized appropriately, for the application at hand.
- Successful, commercially viable, utility-scale installations have focused on short-duration applications (spinning reserve, frequency regulation, ramp control) where alternatives are very costly and/or storage costs are *relatively* modest.
- Storage technologies as used in utility applications are still maturing. Problems should be expected. Most will be solved over time.
- Details regarding each technology's capacity, efficiency, rate of response and other operating parameters and performance guarantees merit careful attention.
- Project-level integration with renewables and grid-level integration of multiple projects are still an art rather than a science.

Takeaways (2)

- Each storage application has to be judged on its own merits. Some applications may not make economic (e.g., time-shifting) or operational sense.
- Forcing the pace of storage adoption could be needlessly costly (Boeing 787). Either allow enough time for storage and ancillary technologies to mature appropriately or shift the risks and costs away from consumers.
- Projects outside California provide a wealth of experience and information. Californians should not have to carry an undue share of the cost burden associated with moving up the learning curve.
- Existing wholesale market mechanisms don't work well for storage (or demand response, combined cycle plants, or eliciting and compensating flexibility). Fixing the market is an important step toward making storage self-sufficient.
- Retail tariffs need to be linked to the wholesale market. Otherwise, customer-connected storage could end up working against the grid instead of in concert with it.

Questions?

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